(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
18 December 2003 (18.12.2003)

PCT

(10) International Publication Number
WO 03/105375 A1

(51) International Patent Classification⁷: H04B 17/00, 7/185

(21) International Application Number: PCT/US03/17781

(22) International Filing Date: 5 June 2003 (05.06.2003)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
10/165,710 7 June 2002 (07.06.2002) US

(71) Applicant: HUGHES ELECTRONICS CORPORATION [US/US]; 200 North Sepulveda Boulevard, El Segundo, CA 90245 (US).

(72) Inventor: CHEN, Ernest, C.; 1025 Via Cordova, San Pedro, CA 90732 (US).

(74) Agents: GRUNEBACH, Georgann, S. et al.; Hughes Electronics Corporation, Building 001, MS A109, P.O. Box 956, El Segundo, CA 90245 (US).

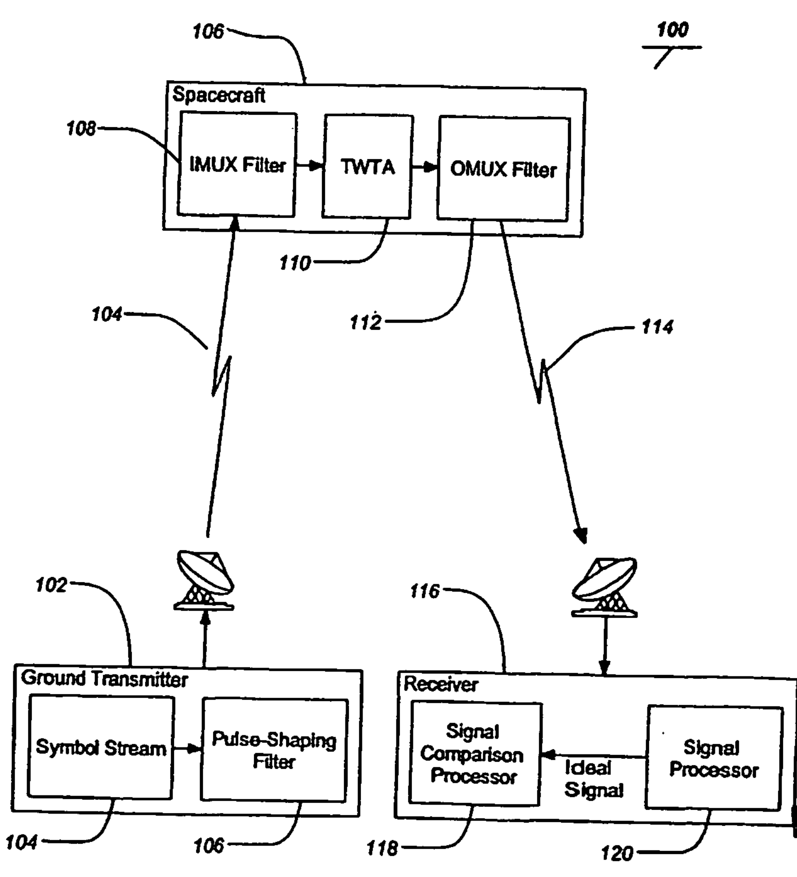
(81) Designated States (*national*): CA, IL, NO.

(84) Designated States (*regional*): European patent (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IT, LU, MC, NL, PT, RO, SE, SI, SK, TR).

Published:
— *with international search report*
— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: SATELLITE TRAVELLING-WAVE TUBE AMPLIFIER ON-LINE NON-LINEARITY MEASUREMENT



(57) Abstract: The present invention discloses methods and systems of measuring transmission performance characteristics, such as from an amplifier. The method comprises the steps of receiving a signal, demodulating the signal, generating an ideal signal from the demodulated signal and estimating the performance characteristic from a difference between the ideal signal and the received signal. A system for measuring a transmission performance characteristic, comprises a demodulator (202) for demodulating a received signal, a signal generator (204) for producing an ideal signal (220) from the demodulated signal and a processor (118) for estimating the performance characteristic from a difference between the ideal signal and the received signal.

WO 03/105375 A1

SATELLITE TRAVELLING-WAVE TUBE AMPLIFIER ON-LINE NON-LINEARITY MEASUREMENT

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This is a continuation-in-part application and claims the benefit under 35 U.S.C. Section 120 of the following co-pending and commonly-assigned U.S. utility patent application, which is incorporated by reference herein:

[0002] Utility Application Serial No. --/---,---, filed ------, by Ernest C. Chen, entitled "LAYERED MODULATION FOR DIGITAL SIGNALS," attorneys' docket number PD-200181 (109.0051-US-01).

BACKGROUND OF THE INVENTION

1. Field of the Invention.

[0003] The present invention relates generally to systems and methods for measuring amplifier performance, and particularly for measuring travelling wave tube amplifier (TWTA) performance in satellite systems.

2. Description of the Related Art.

[0004] Travelling wave tube amplifiers (TWTA) are a key component for many communication systems. As with many components of communication systems there is a need to monitor and diagnose the operation of the TWTAs in use. There is particularly a need for such techniques in systems which require feedback of TWTA performance characteristics to optimize their operation. Also, TWTA measurements may be useful in communication systems which employ layered modulation, such as described in copending and commonly assigned application serial number XX/XXX,XXX, filed on XXXXXX, by Ernest Chen and entitled "LAYERED MODULATION FOR DIGITAL SIGNALS", which is hereby incorporated by reference herein, are examples of such systems.

[0005] Currently measurements of TWTA performance are obtained by shutting down the transponder service and driving the TWTA at varying input power levels, and measuring amplitude and phase responses as a function of input power level. As it is

often desirable to maximize the operating time of the transponders in communication systems, techniques which enable measuring performance of the TWTA while it remains operating are very useful.

[0006] In such systems, the TWTA characteristics must be measured while the TWTA operates. The present invention meets the described needs.

SUMMARY OF THE INVENTION

[0007] The present invention discloses a system and methods of measuring transmission performance characteristics, such as from an amplifier. The method comprises the steps of receiving a signal, demodulating the signal, generating an ideal signal from the demodulated signal and estimating the performance characteristic from a difference between the ideal signal and the received signal. A system for measuring a transmission performance characteristic comprises a demodulator for demodulating a received signal, a signal generator for producing an ideal signal from the demodulated signal and a processor for estimating the performance characteristic from a difference between the ideal signal and the received signal.

[0008] The present invention is particularly useful for monitoring TWTA performance. In addition, the invention may be used to diagnose system problems that may be caused by the TWTAs. TWTA linearity performance may be efficiently summarized in two fundamental graphs, an AM-AM curve and an AM-PM curve, which map an input amplitude modulation to an output amplitude modulation and an output phase modulation, respectively. The invention may be used to produce accurate AM-AM and AM-PM curves. Such curves may be used in systems which may employ active feedback of TWTA characteristics, such as in layered modulation transmission schemes.

[0009] The invention provides the advantage that it may be performed without taking the TWTA off line. In addition, the present invention may be employed regardless of the signal format, e.g. QPSK, 8PSK, 16QAM, etc. Although the invention is well suited for digital signal formats, it is not limited to these applications. Analog signal formats may require signal sampling and timing synchronization, however. The invention may also be

used at anytime and from any place so long as a signal transmitted by the transponder may be captured for processing. In addition, the invention provides very accurate results with errors as small as -50 dB rms for signals with sufficient carrier-to-interference ratio (CIR) and carrier-to-noise ratio (CNR).

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] Referring now to the drawings in which like reference numbers represent corresponding parts throughout:

[0011] FIG. 1 is a signal path block diagram of an embodiment employing the invention;

[0012] FIGs. 2A - 2B are block diagrams of the apparatus and method of the present invention;

[0013] FIG. 3 is an AM-AM scattergram and curve fitting from the signal data with no noise;

[0014] FIG. 4 is an AM-PM scattergram and curve fitting from the signal data with no noise;

[0015] FIG. 5 is an AM-AM scattergram and curve fitting from a signal with 7 dB CNR;

[0016] FIG. 6 is an AM-PM scattergram and curve fitting from a signal with 7 dB CNR;

[0017] FIG. 7 depicts an general characteristic of an AM-AM map biased with noise;

[0018] FIG. 8 is a first example of TWTA non-linearity for a linearized TWTA;

[0019] FIG. 9 is a second example of TWTA non-linearity for a non-linearized TWTA;

[0020] FIG. 10 is a simulated map showing true and fitting curves for a non-linearized TWTA with matched filtering;

[0021] FIG. 11 is a graph of an estimated AM-AM curve with the raw data;

[0022] FIG. 12 is a graph of an estimated AM-PM curve with the raw data;

[0023] FIG. 13 is a graph of the curve fitting errors;

[0024] FIG. 14 is an input data histogram of the AM distribution;

[0025] FIG. 15 is a simulated map showing true and fitting curves for a linearized TWTA with matched filtering; and

[0026] FIG. 16 is a simulated map showing true and fitting curves for a linearized TWTA with matched filtering with a reduced CNR.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

[0027] In the following description, reference is made to the accompanying drawings which form a part hereof, and which show, by way of illustration, several embodiments of the present invention. It is understood that other embodiments may be utilized and structural changes may be made without departing from the scope of the present invention.

[0028] FIG. 1 is a simplified signal path block diagram of an embodiment employing the invention. The invention measures and characterizes the difference between a signal 114 received at a receiver 116 and an ideal signal, which may represent the transmitted signal 104. From this difference the influence of intervening hardware and environments may be determined. Estimating performance of a TWTA used in a satellite broadcast system is one example of application which may especially benefit from the present invention.

[0029] In the typical system 100 of FIG. 1, a ground transmitter 102 produces a signal which includes a symbol stream 104 that may be processed by a pulse-shaping filter 106. The signal is transmitted through an uplink 104 to a spacecraft 106 or other suitable platform which may include an input multiplexing (IMUX) filter 108 for filtering out undesirable signal components outside the frequency band of interest. A TWTA 110 is then used to amplify the signal. An output multiplexing (OMUX) filter 112 may then cleanse the output signal in the extraneous frequency ranges before it is conveyed through the downlink 114 to a receiver 116.

[0030] The receiver 116 which receives the signal includes signal processor 120 which extracts the symbol stream and carrier frequency from the incoming signal and generates an ideal signal, i.e. a signal without the effects of the TWTA and noise. The ideal signal

is then used in a comparison processor 118 to produce the TWTA performance maps. The details of the invention concerning the generation of the performance maps will be described below in the discussion of FIGs. 2A - 2B.

[0031] Typically, the TWTA performance maps will comprise measurements of the output amplitude modulation versus the input amplitude modulation (the AM-AM map) and the output phase modulation versus the input amplitude modulation (the AM-PM map). In the present invention the received signal represents the amplifier output (plus noise) and the generated ideal signal represents the amplifier input. In addition to diagnosing and monitoring the amplifier, these performance maps may then be used to facilitate and/or improve reception of different layers of a system using a layered modulation transmission scheme.

[0032] FIGS. 2A and 2B are block diagrams of the basic system of the invention 200. All of the described functions may be carried out within a receiver 116 used in a direct broadcast satellite system having a basic architecture as described in FIG 1. The appropriate signal section is captured and demodulated by demodulator 202 which aligns symbol timing and removes any residual carrier frequency and phase in the signal. The demodulated signal is used in a signal generator 204 to generate an ideal signal, i.e. one representing the pre-transmitted signal. In the case of a digital signal, the signal will be further decoded to obtain the signal symbols which will be used to generate the ideal signal. The difference between the ideal signal and the received signal is used by processors 206, 210, 208, 212 to estimate a transmission performance characteristic. Only a small section of the received signal, on the order of a few thousand symbols, may be needed to obtain an estimate.

[0033] FIG. 2A depicts an embodiment where the performance characteristic is estimated from a difference between the ideal signal (noise-free and without TWTA non-linearity) and the received signal after demodulation. Because the ideal signal is generated from only the symbols and symbol timing, obtaining the estimate from the received signal after demodulation simplifies the processing.

[0034] FIG. 2B depicts an embodiment where the performance characteristic is estimated from a difference between the ideal signal and the received signal before demodulation. In this case, the ideal signal must also be generated with the carrier frequency of the received signal. This may be done by adding the demodulated symbol timing and carrier frequency and phase to the ideal signal.

[0035] If necessary, forward error correction (FEC) may be applied to the demodulated signal as part of decoding to ensure that all recovered symbols are error-free.

[0036] In either embodiment (FIG. 2A or 2B) the ideal signal and the received signal are next used in processors 206, 208 to pair and sort data points of the two signals. These processors 206, 208 characterize a relationship between an input signal and an output signal of the amplifier. In this case, the input signal is represented by the generated ideal signal 220 (modulated or otherwise) and the output signal is represented by the received signal. The X-axis of an AM-AM scattergram plots the magnitudes of the ideal signal samples with perfect TWTA linearity, and the Y-axis consists of the magnitudes of the received signal samples including the TWTA non-linearity (and noise). An AM-PM scattergram is similarly formed. The X-axis is the same as that for the AM-AM scattergram, and the Y-axis consists of all phase differences between the corresponding samples with and without TWTA non-linearity. Finally, the data points of the ideal signal and the corresponding data points of the received signal are processed by a processor 210, 212 to form a line through curve fitting, such as with a polynomial. The curve fitting processor 210, 212 may be separate or part of the processor 206, 208 which paired and sorted the data points. The result is an estimate of the desired performance characteristic of the TWTA 214, 216.

[0037] FIG. 2C outlines the flow of a method of the present invention. A signal is received at block 222. The signal is demodulated at block 224. Then an ideal signal is generated from the demodulated signal at block 226. Finally, a performance characteristic is estimated from a difference between the ideal signal and the received signal at block 228. The following examples will illustrate details of the present invention as applied to TWTA performance measurement.

[0038] FIGS. 3 and 4 show example scattergrams from simulated QPSK signals with no noise in the signal. FIG. 3 is an AM-AM scattergram and FIG. 4 is an AM-PM scattergram. In this case, the sample scattering in the scattergrams is primarily due to the IMUX and OMUX filters which were not included in the reconstruction of the distortion-free signal.

[0039] Next, each scattergram is fitted with a curve by a minimum-mean-square (mms) error process. For best fitting performance with low-degree polynomials, the X-axis may be divided into several segments. Curve fitting is performed on each segment, and the fitting polynomials are then pieced together from segment to segment. The concatenated curves form the estimates of the AM-AM and AM-PM maps for the transponder.

[0040] As an example, FIG. 3 shows the fitting process for the AM-AM curve with simulated data, when no noise is present in the received signal. The overall fitting error is –42 dB. Likewise, FIG. 4 shows the results of an AM-PM estimate from the same set of received and reconstructed signals. The minimum-mean-square (mms) fitting error is –35 dB in this case. The mms error between the fitting curves and the actual AM-AM and AM-PM curves, which are of importance here, are found to be quite low in these cases, both less than –50 dB.

[0041] FIGS. 5 and 6 show scattergrams for a signal with a carrier to noise ration (CNR) of approximately 7 dB. FIG. 5 presents AM-AM data and relevant curves. Curve 500 represents the true AM-AM characteristic of the amplifier as can be seen in FIG. 3, whereas curve 502 represents the fitting curve. The plot demonstrates that at low magnitudes the interpolated map deviates more from the actual amplifier response with a bias. This is due to the effect of a noise floor of the signal. In addition, less data is available for lower magnitudes, further degrading the fitting line. A similar result is seen in the AM-PM curve of FIG. 6 between the true amplifier phase response curve 600 (as in FIG. 4) and the interpolated curve 602. Since, most of the signal samples concentrate near amplifier saturation, the quality of the small-magnitude portion of the curve is not critical. Accuracy of the curves at lower magnitudes may be improved to reduce the bias, however, by either employing a larger antenna or extrapolating the curve to this region

with a straight line slope as shown by the curve 504 in FIG. 5, recognizing the fact that amplifier amplitude is nearly linear and phase is nearly constant for small-magnitude signals.

[0042] FIG. 7 depicts an example AM-AM map biased with noise. $s_0 = f(s_i)$ represents the true AM-AM curve without noise. N_0 is the downlink noise power and. $f(s_i) + N_0$ represents the AM-AM measurement with noise. Therefore, $\hat{f}(s_i) = \widehat{\left(f(s_i) + N_0\right)} - \hat{N}_0$, where symbol "^" represents an estimate. When s_i is small, i.e. in the linear region of the amplifier, $f(s_i) = s_0 \cong s_i$ (ignoring a constant scale factor). $\hat{N}_0$ is estimated relative to the signal from the captured data. Similarly, for the AM-PM estimate the curve accuracy may be improved by the knowledge that the output phase is approximately constant when the input magnitude is small. In general, a known characteristic response of a performance characteristic to be actively mapped by the invention may be incorporated to refine the particular curve interpolation process.

[0043] FIGS. 8 and 9 illustrate examples of two different TWTAs for the purpose of testing the invention. FIG. 8 illustrates a linearized TWTA and FIG. 9 illustrates a non-linearized TWTA. Other developed models may be similarly tested with the present invention. For example, A. Saleh has developed such TWTA models. See A. Saleh, "Frequency-Independent and Frequency-Dependent Nonlinear Models of TWTA Amplifiers," IEEE Transactions on Communications, vol. COM-29, No. 11, November 1981, pp. 1715-1720 which is incorporated by reference herein.

[0044] Just as the known characteristic response of the TWTA may be incorporated into the curve fitting process, the impact of filtering in the overall system may also be accounted for by the interpolation process of the present invention. For a signal with a symbol rate of 20 MHz, the OMUX, which works on a signal at the output of the TWTA, may have a one-sided bandwidth much wider than 12 MHz. The receiver 116 may typically employ a front end filter (e.g. a low pass filter) with a bandwidth of approximately 17 MHz. The pulse-shaping filter at the receiver may have a bandwidth of

12 MHz. The receiver matched filter would be the most influential of the filters and its presence tends to degrade TWTA map measurement. In general, it is desirable to minimize filtering on the received signal in order to retain as much spectral re-growth effect of the TWTA non-linearity for best measurement accuracy. This is demonstrated in the following example.

[0045] FIGS. 10 - 14 show simulated maps of AM-AM and AM-PM curves and related information for a non-linearized TWTA. FIG. 10 is a simulated map showing true and fitting curves when the effect of the matched filter is included. The signal has a CNR of 99 dB and utilizes a non-linearized TWTA. Although the effects of the receiver filter and the OMUX have not been included, their influence is negligible. The fitting was performed using approximately 24K samples at 51 MHz sampling frequency in eight segments. (The data symbol rate is 20 MHz.) Notice that only a portion of the full non-linearity shows up in the measured data. FIGS. 11 and 12 show, respectively, the fitting AM-AM and AM-PM curves with the raw data. FIG. 13 shows the fitting error for the two curves. Incidentally, FIG. 14 is an input data histogram showing that most of the data occurs less than 10 dB from saturation.

[0046] FIG. 15 shows simulated maps of AM-AM and AM-PM curves for a linearized TWTA. The parameters are identical to those of the example of FIG. 10.

[0047] FIG. 16 shows simulated maps of AM-AM and AM-PM curves for a linearized TWTA. In this case, the CNR is a practical 14.1 dB and a sampling rate of 50 MHz is used. The parameters are otherwise identical to those of the example of FIG. 10.

CONCLUSION

[0048] The foregoing description including the preferred embodiment of the invention has been presented for the purposes of illustration and description. It is not intended to be exhaustive or to limit the invention to the precise form disclosed. Many modifications and variations are possible in light of the above teaching. It is intended that the scope of the invention be limited not by this detailed description, but rather by the claims appended hereto. The above specification, examples and data provide a complete description of the

manufacture and use of the invention. Since many embodiments of the invention can be made without departing from the scope of the invention, the invention resides in the claims hereinafter appended.

WHAT IS CLAIMED IS:

1. A method of measuring a transmission performance characteristic, comprising the steps of:

receiving a signal;

demodulating the signal;

generating an ideal signal from the demodulated signal;

estimating the performance characteristic from a difference between the ideal signal and the received signal.

2. The method of Claim 1, wherein the performance characteristic is estimated from a difference between the ideal signal and the received signal after demodulation.

3. The method of Claim 1, wherein the performance characteristic is estimated from a difference between the ideal signal and the received signal before demodulation.

4. The method of Claim 1, wherein the step of estimating the performance characteristic includes fitting a curve of the received signal versus the ideal signal.

5. The method of Claim 4, wherein the curve is an AM-AM plot.

6. The method of Claim 4, wherein the curve is an AM-PM plot.

7. The method of Claim 1, wherein the ideal signal is represented by data points of a measured property and the received signal is represented by corresponding data points of a corresponding measured property and the data points and corresponding data points are paired across a range.

8. The method of Claim 7, wherein the measured property of the ideal signal is amplitude.

9. The method of Claim 7, wherein the corresponding measured property of the received signal is amplitude.

10. The method of Claim 7, wherein the corresponding measured property of the received signal is phase.

11. The method of Claim 7, wherein the range is limited to signal power levels above a noise floor of the received signal.

12. The method of Claim 7, wherein received signal is amplified and the range is limited to signal power levels below a saturation level of the amplified signal.

13. The method of Claim 7, wherein the step of estimating the performance characteristic includes fitting a curve for the paired data points and corresponding data points.

14. The method of Claim 13, wherein fitting the curve comprises performing a minimum mean square operation across a range.

15. The method of Claim 13, wherein fitting the curve incorporates a known characteristic response of the performance characteristic.

16. The method of Claim 1, wherein the signal is digital and the step of demodulating includes decoding the signal to obtain a symbol stream, a carrier frequency and symbol timing.

17. The method of Claim 16, wherein the ideal signal is generated from the symbol stream, carrier frequency and symbol timing.

18. The method of Claim 17, wherein a pulse shaping filter is used with the symbol stream, carrier frequency and symbol timing to generate the ideal signal.

19. A system for measuring a transmission performance characteristic, comprising:

a demodulator for demodulating a received signal;

a signal generator for producing an ideal signal from the demodulated signal; and

a processor for estimating the performance characteristic from a difference between the ideal signal and the received signal.

20. The system of Claim 19, wherein the performance characteristic is estimated from a difference between the ideal signal and the received signal after demodulation.

21. The system of Claim 19, wherein the performance characteristic is estimated from a difference between the ideal signal and the received signal before demodulation.

22. The system of Claim 19, wherein estimating the performance characteristic includes fitting a curve of the received signal versus the ideal signal.

23. The system of Claim 22, wherein the curve is an AM-AM plot.

24. The system of Claim 22, wherein the curve is an AM-PM plot.

25. The system of Claim 19, wherein the ideal signal is represented by data points of a measured property and the received signal is represented by corresponding data points of a corresponding measured property and the data points and corresponding data points are paired across a range.

26. The system of Claim 25, wherein the measured property of the ideal signal is amplitude.

27. The system of Claim 25, wherein the corresponding measured property of the received signal is amplitude.

28. The system of Claim 25, wherein the corresponding measured property of the received signal is phase.

29. The system of Claim 25, wherein the range is limited to signal power levels above a noise floor of the received signal.

30. The system of Claim 25, wherein received signal is amplified and the range is limited to signal power levels below a saturation level of the amplified signal.

31. The system of Claim 25, wherein estimating the performance characteristic includes fitting a curve for the paired data points and corresponding data points.

32. The system of Claim 31, wherein fitting the curve comprises performing a minimum mean square operation across a range.

33. The system of Claim 31, wherein fitting the curve incorporates a known characteristic response of the performance characteristic.

34. The system of Claim 19, wherein the signal is digital and the step of demodulating includes decoding the signal to obtain a symbol stream, a carrier frequency and symbol timing.

35. The system of Claim 34, wherein the ideal signal is generated from the symbol stream, carrier frequency and symbol timing.

36. The system of Claim 35, wherein a pulse shaping filter is used with the symbol stream, carrier frequency and symbol timing to generate the ideal signal.

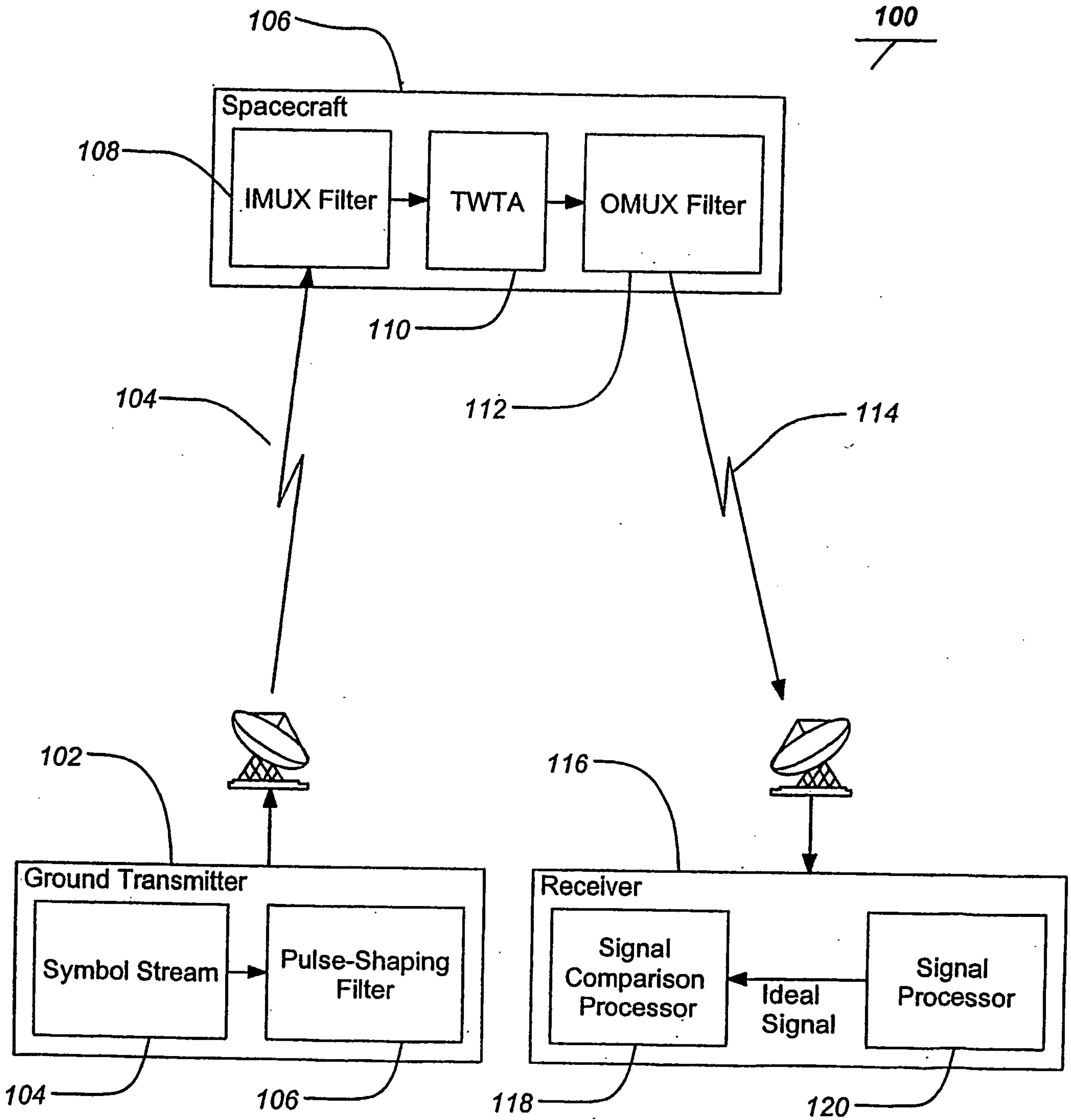

100
106
Spacecraft
108
IMUX Filter
TWTA
OMUX Filter
110
112
104
114
102
116
Ground Transmitter
Symbol Stream
Pulse-Shaping Filter
Receiver
Signal Comparison Processor
Ideal Signal
Signal Processor
104
106
118
120

FIG. 1

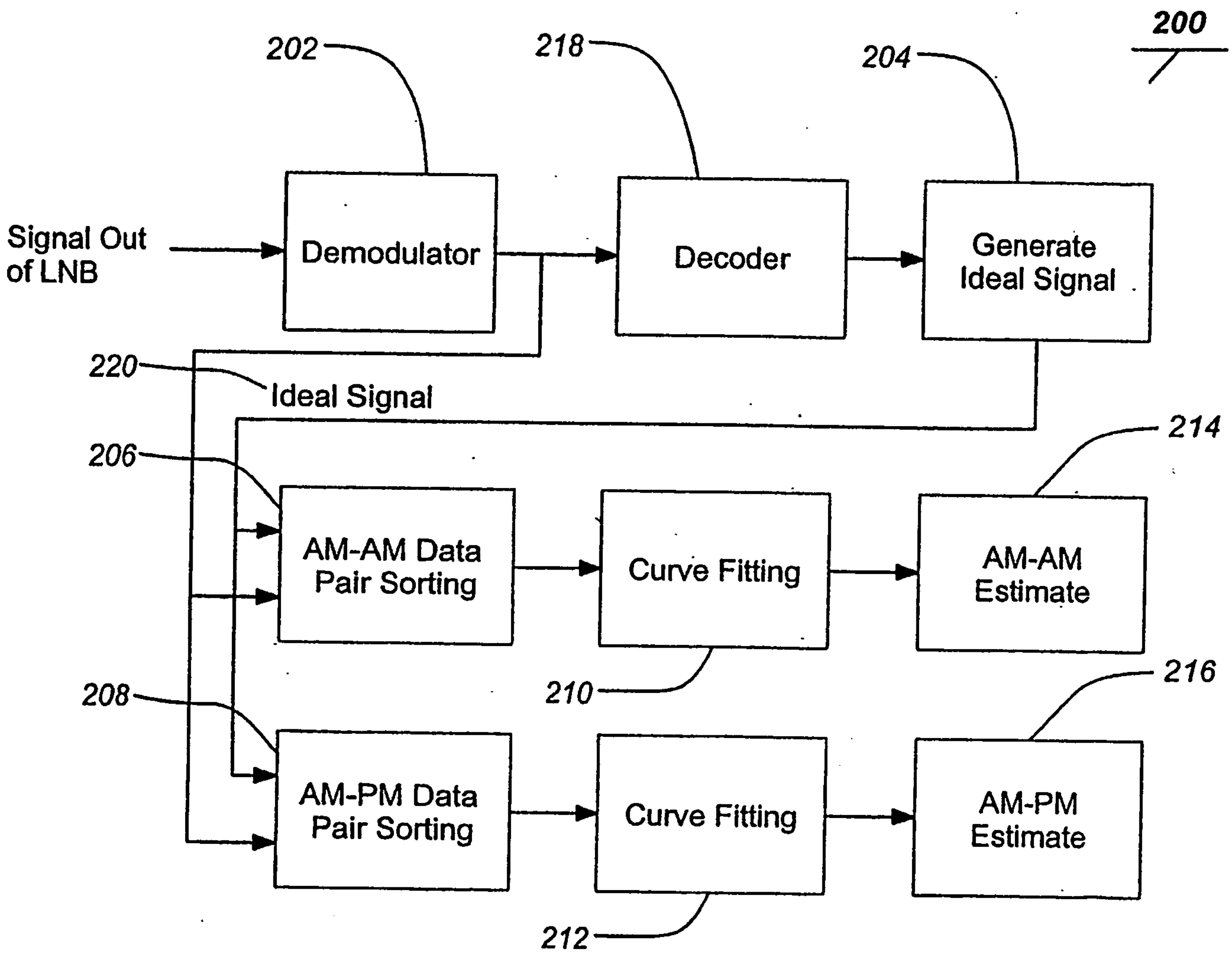

200
202
218
204
Signal Out of LNB
Demodulator
Decoder
Generate Ideal Signal
220
Ideal Signal
206
214
AM-AM Data Pair Sorting
Curve Fitting
AM-AM Estimate
210
208
216
AM-PM Data Pair Sorting
Curve Fitting
AM-PM Estimate
212

FIG. 2A

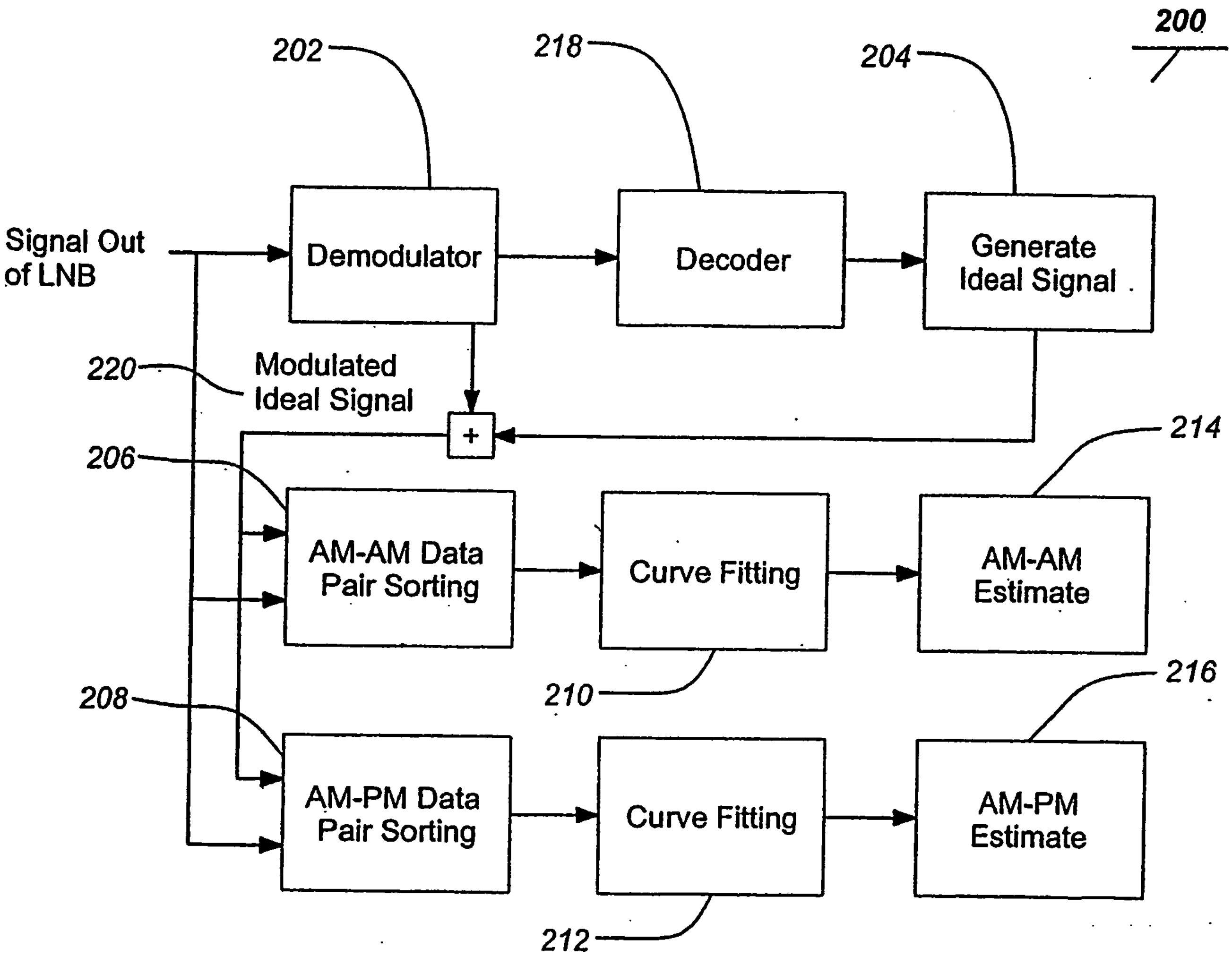

200
202
218
204
Signal Out of LNB
Demodulator
Decoder
Generate Ideal Signal
220
Modulated Ideal Signal
+
206
214
AM-AM Data Pair Sorting
Curve Fitting
AM-AM Estimate
210
208
216
AM-PM Data Pair Sorting
Curve Fitting
AM-PM Estimate
212

FIG. 2B

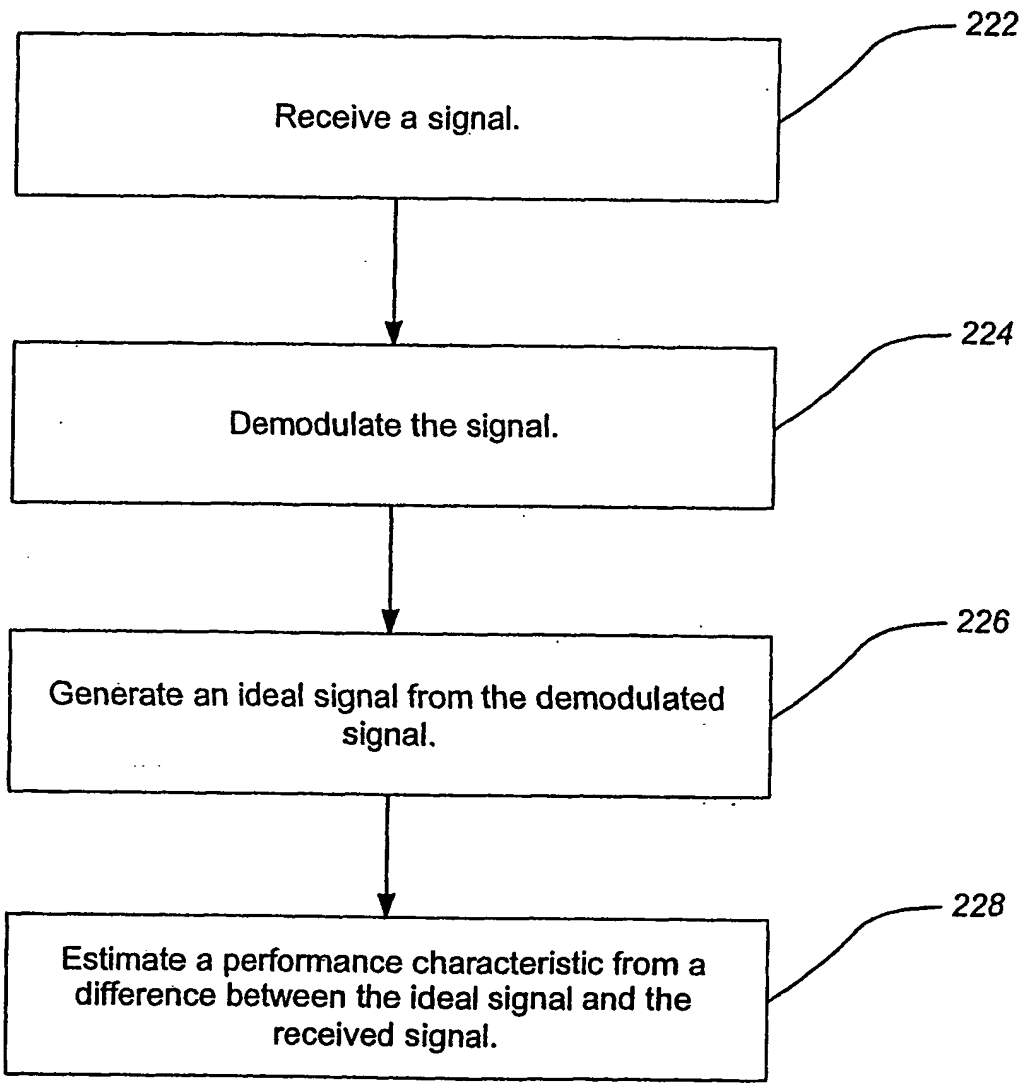

222
Receive a signal.
224
Demodulate the signal.
226
Generate an ideal signal from the demodulated signal.
228
Estimate a performance characteristic from a difference between the ideal signal and the received signal.

FIG. 2C

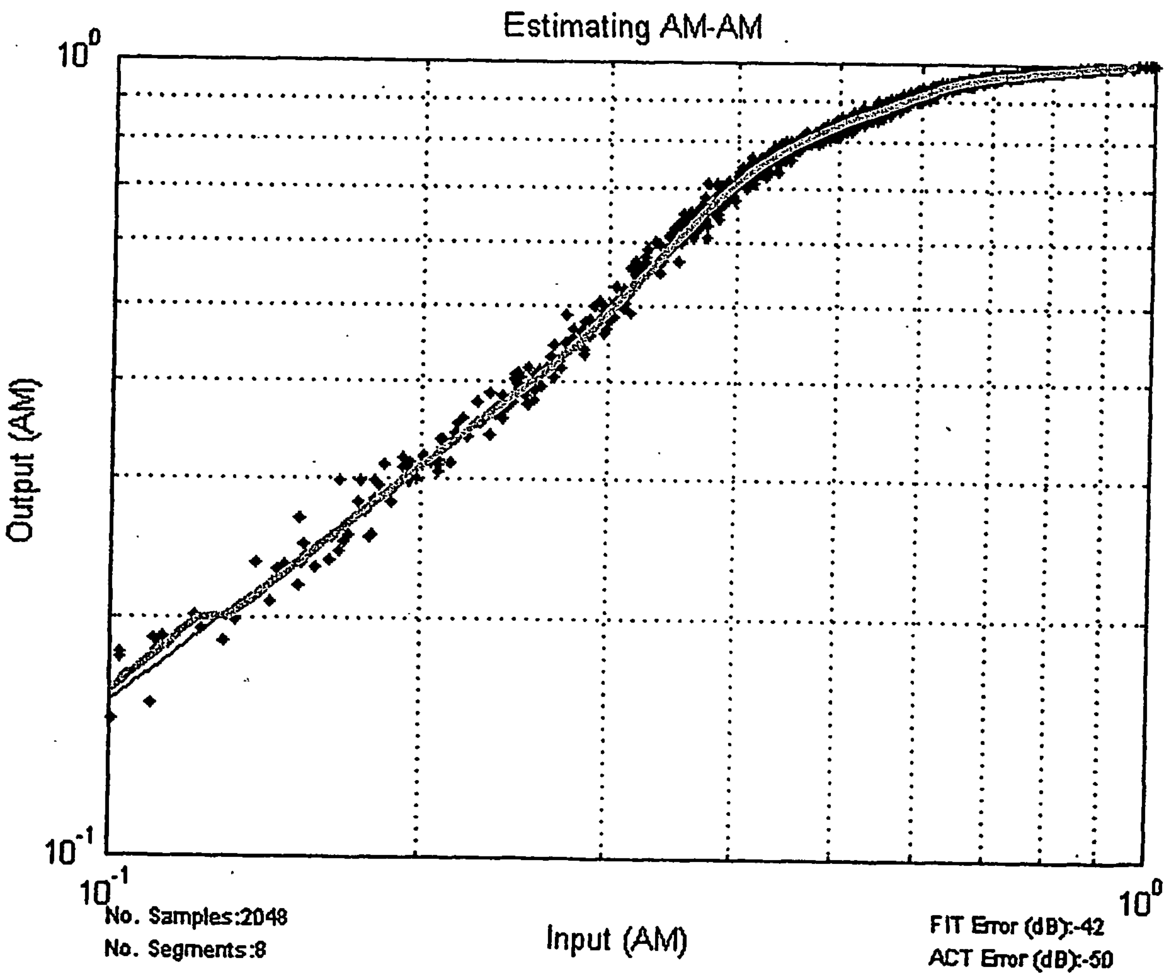

Estimating AM-AM
10^0
10^{-1}
Output (AM)
10^{-1}
10^0
No. Samples:2048
No. Segments:8
Input (AM)
FIT Error (dB):-42
ACT Error (dB):-50

FIG. 3

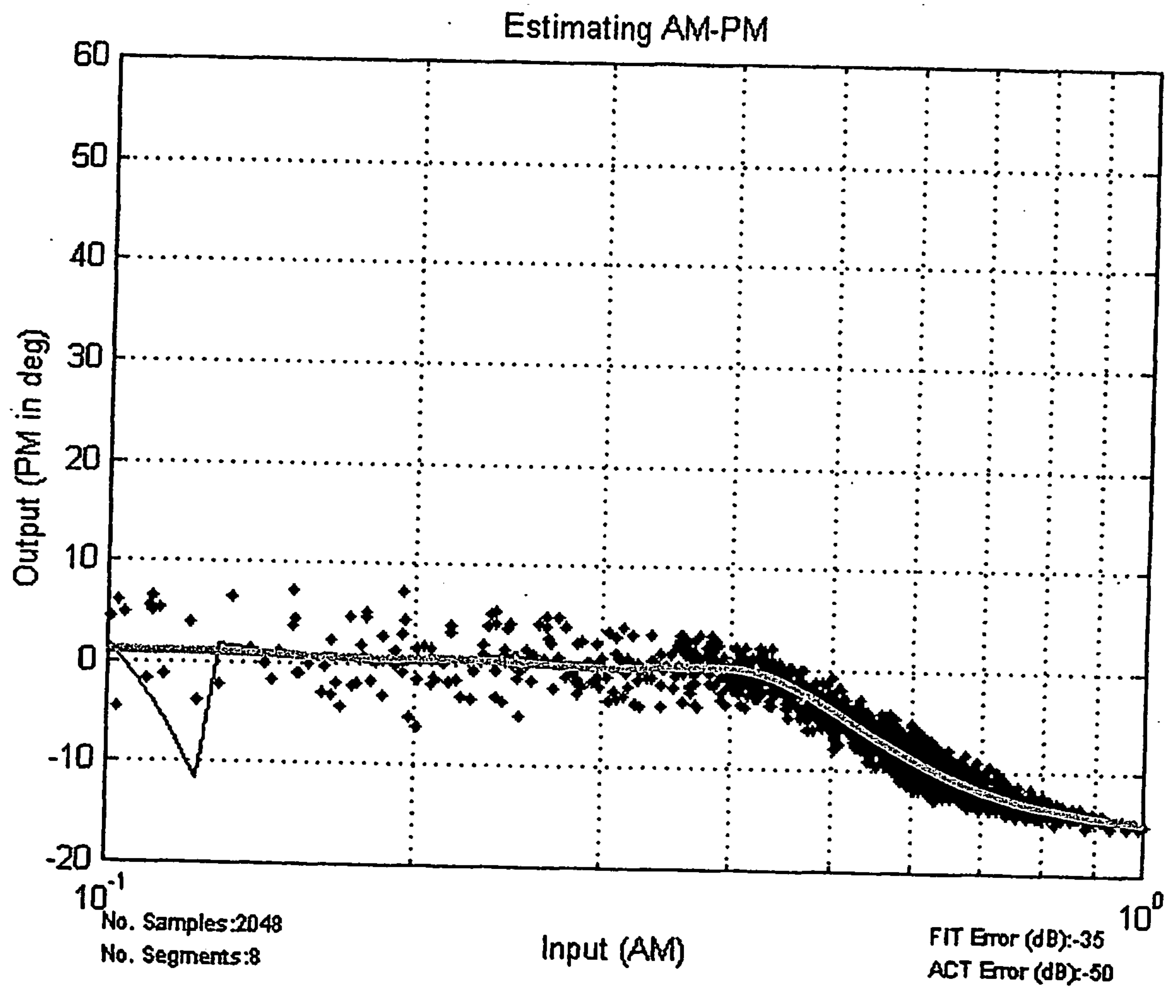

Estimating AM-PM
60
50
40
30
20
10
0
-10
-20
Output (PM in deg)
10^{-1}
10^{0}
Input (AM)
No. Samples:2048
No. Segments:8
FIT Error (dB):-35
ACT Error (dB):-50

FIG. 4

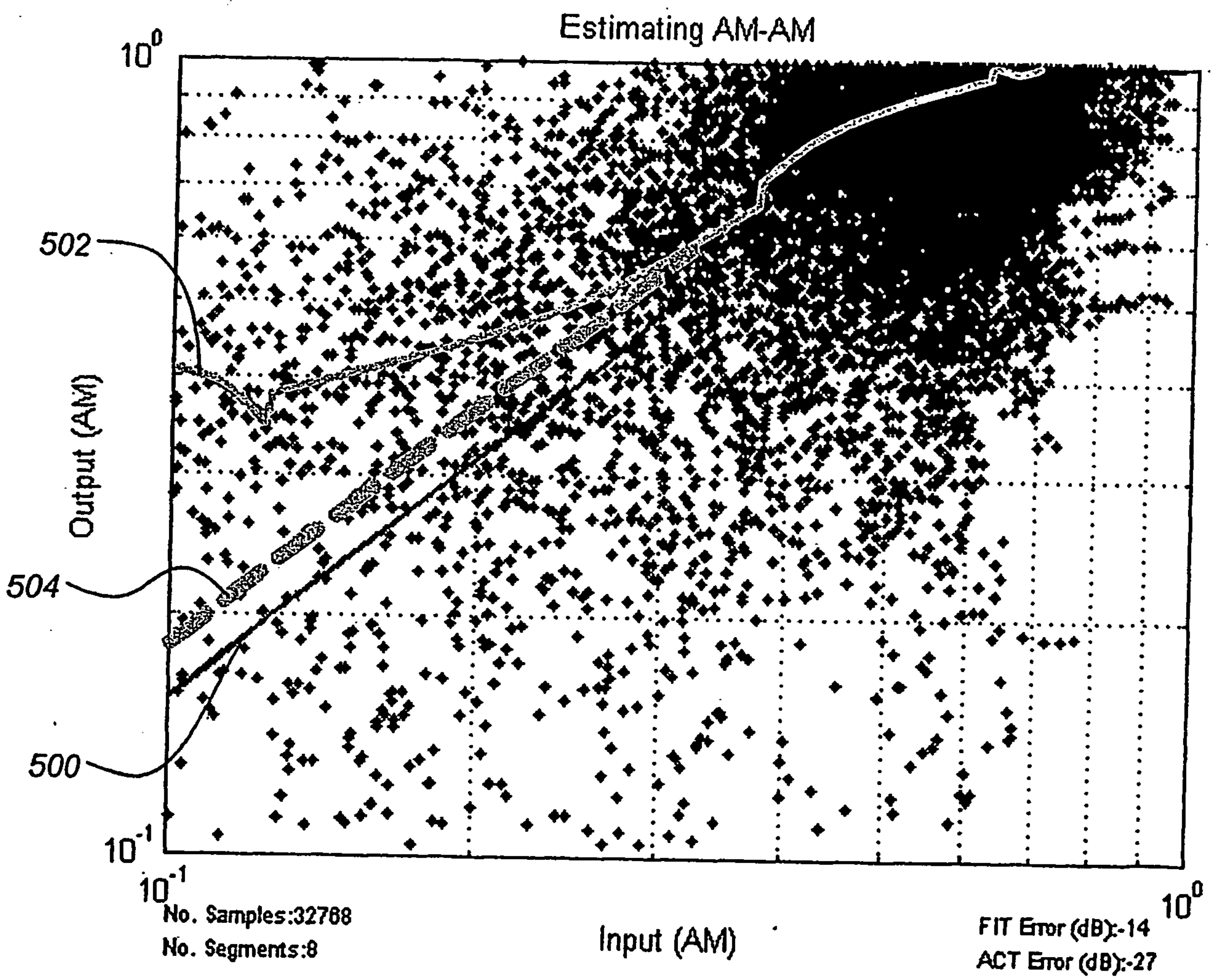

Estimating AM-AM
10^0
10^{-1}
Output (AM)
Input (AM)
10^{-1}
10^0
502
504
500
No. Samples:32768
No. Segments:8
FIT Error (dB):-14
ACT Error (dB):-27

FIG. 5

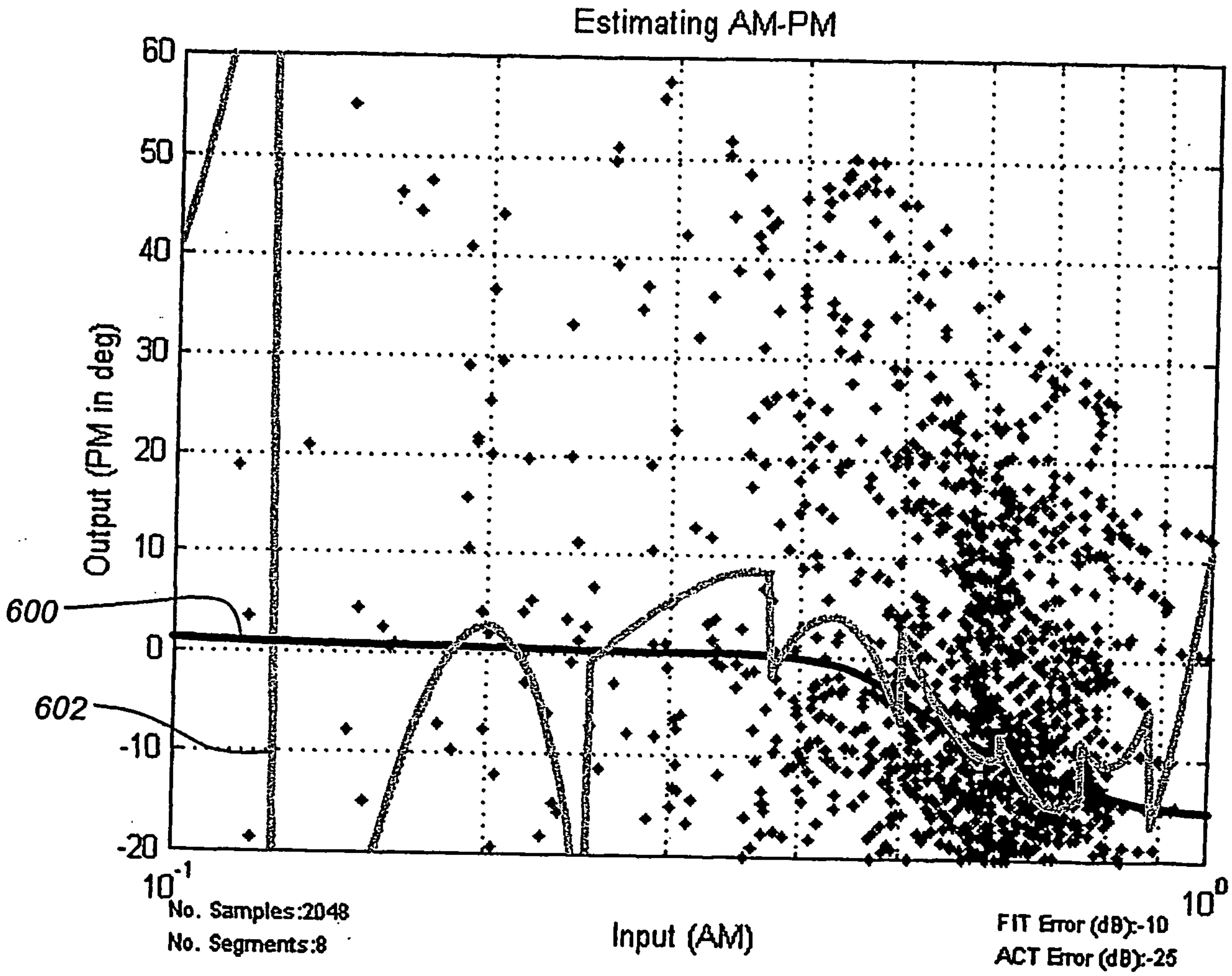

Estimating AM-PM
60
50
40
30
20
10
0
-10
-20
Output (PM in deg)
600
602
10^{-1}
10^{0}
Input (AM)
No. Samples:2048
No. Segments:8
FIT Error (dB):-10
ACT Error (dB):-25

FIG. 6

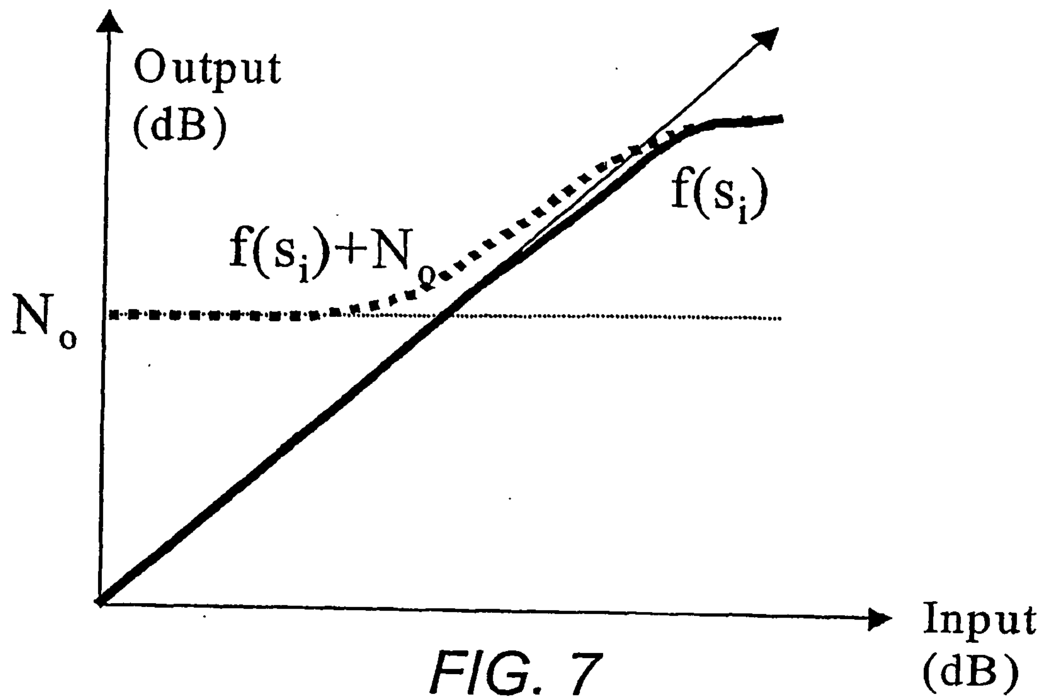

Output
(dB)
N_o
$f(s_i)+N_o$
$f(s_i)$
Input
(dB)

FIG. 7

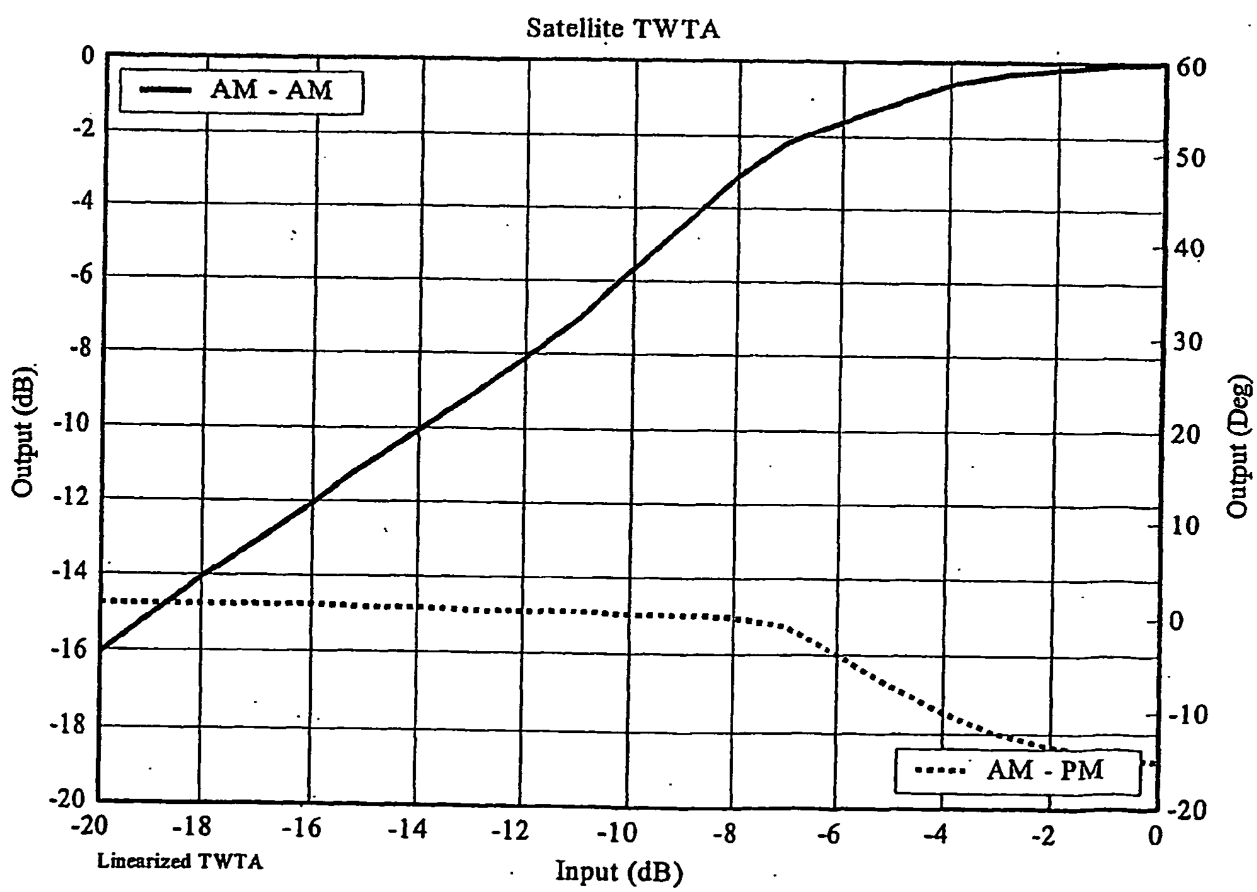
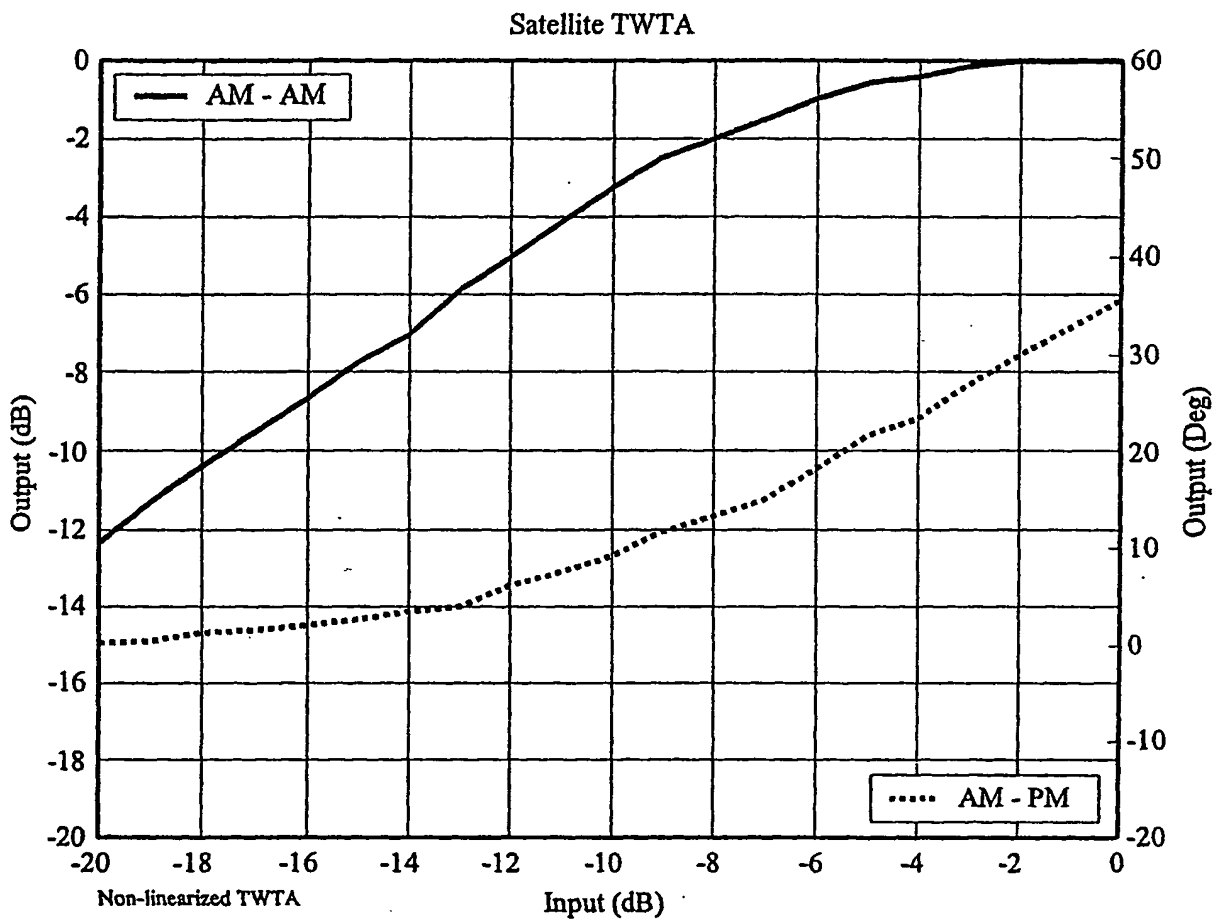

Satellite TWTA
AM - AM
AM - PM
Output (dB)
Output (Deg)
Input (dB)
Linearized TWTA
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
60
50
40
30
20
10
0
-10
-20
-20
-18
-16
-14
-12
-10
-8
-6
-4
-2
0

FIG. 8



Satellite TWTA
AM - AM
AM - PM
Output (dB)
Output (Deg)
Input (dB)
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
60
50
40
30
20
10
0
-10
-20
-20
-18
-16
-14
-12
-10
-8
-6
-4
-2
0
Non-linearized TWTA

FIG. 9

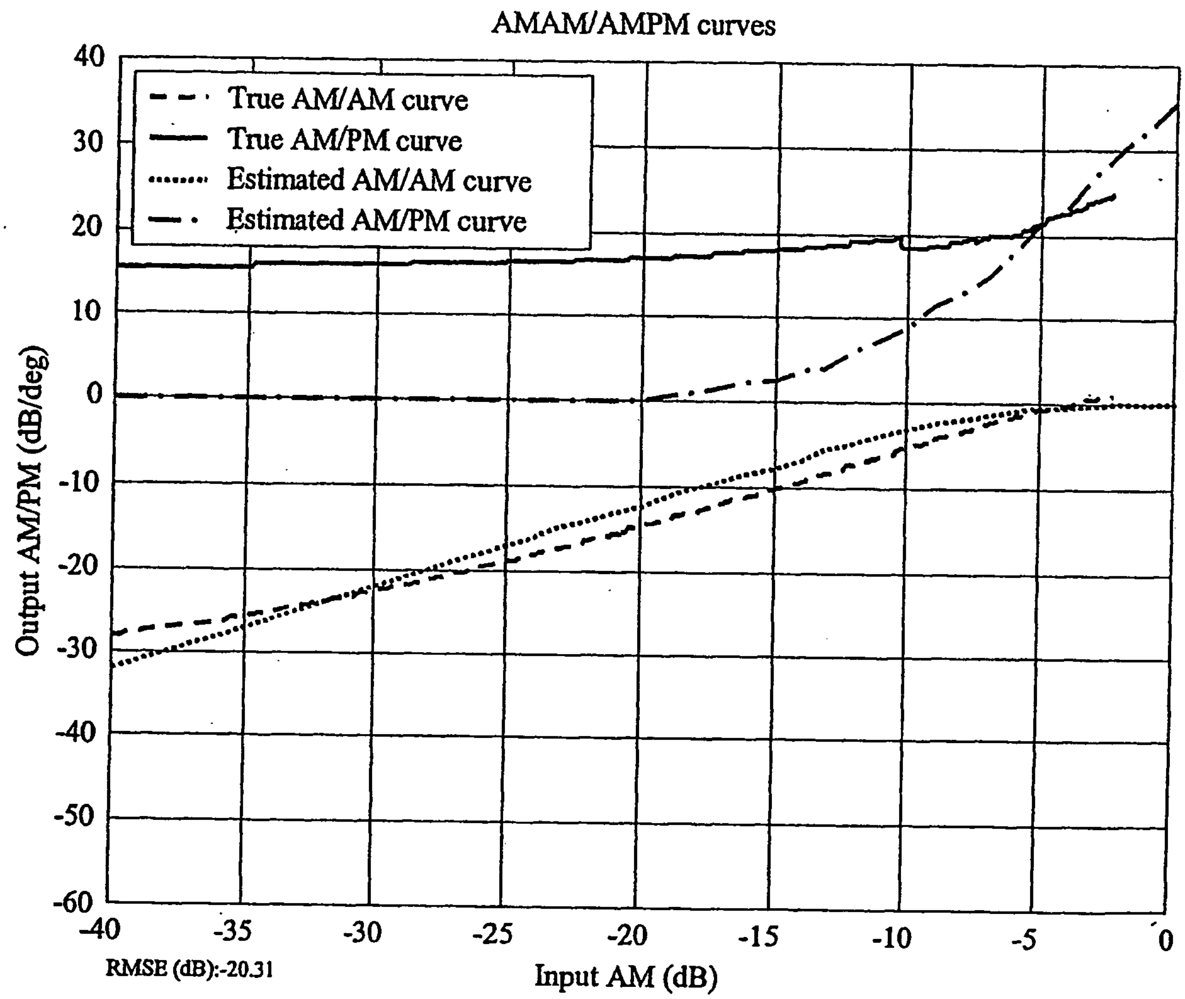

AMAM/AMPM curves
True AM/AM curve
True AM/PM curve
Estimated AM/AM curve
Estimated AM/PM curve
40
30
20
10
0
-10
-20
-30
-40
-50
-60
Output AM/PM (dB/deg)
-40
-35
-30
-25
-20
-15
-10
-5
0
Input AM (dB)
RMSE (dB):-20.31

FIG. 10

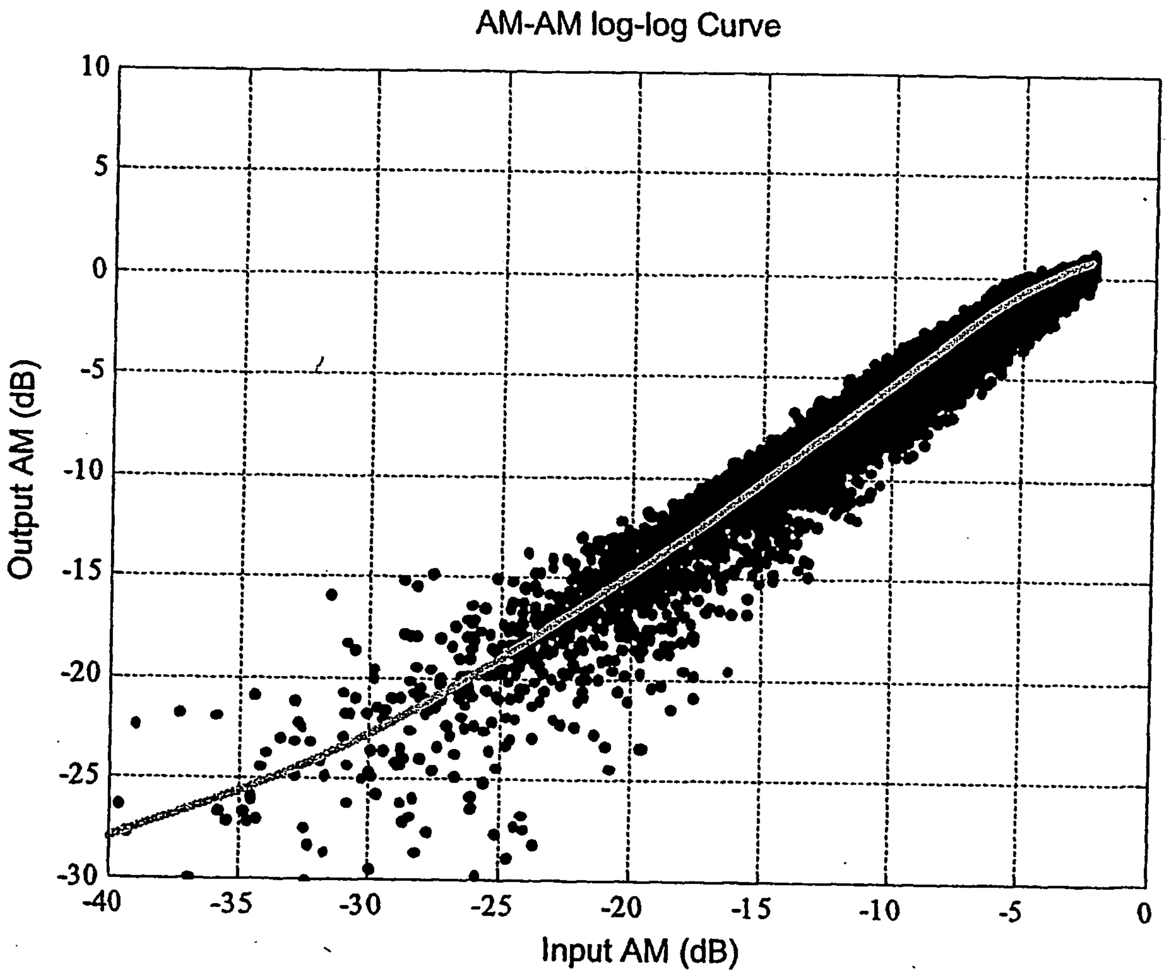

AM-AM log-log Curve
10
5
0
-5
-10
-15
-20
-25
-30
Output AM (dB)
-40
-35
-30
-25
-20
-15
-10
-5
0
Input AM (dB)

FIG. 11

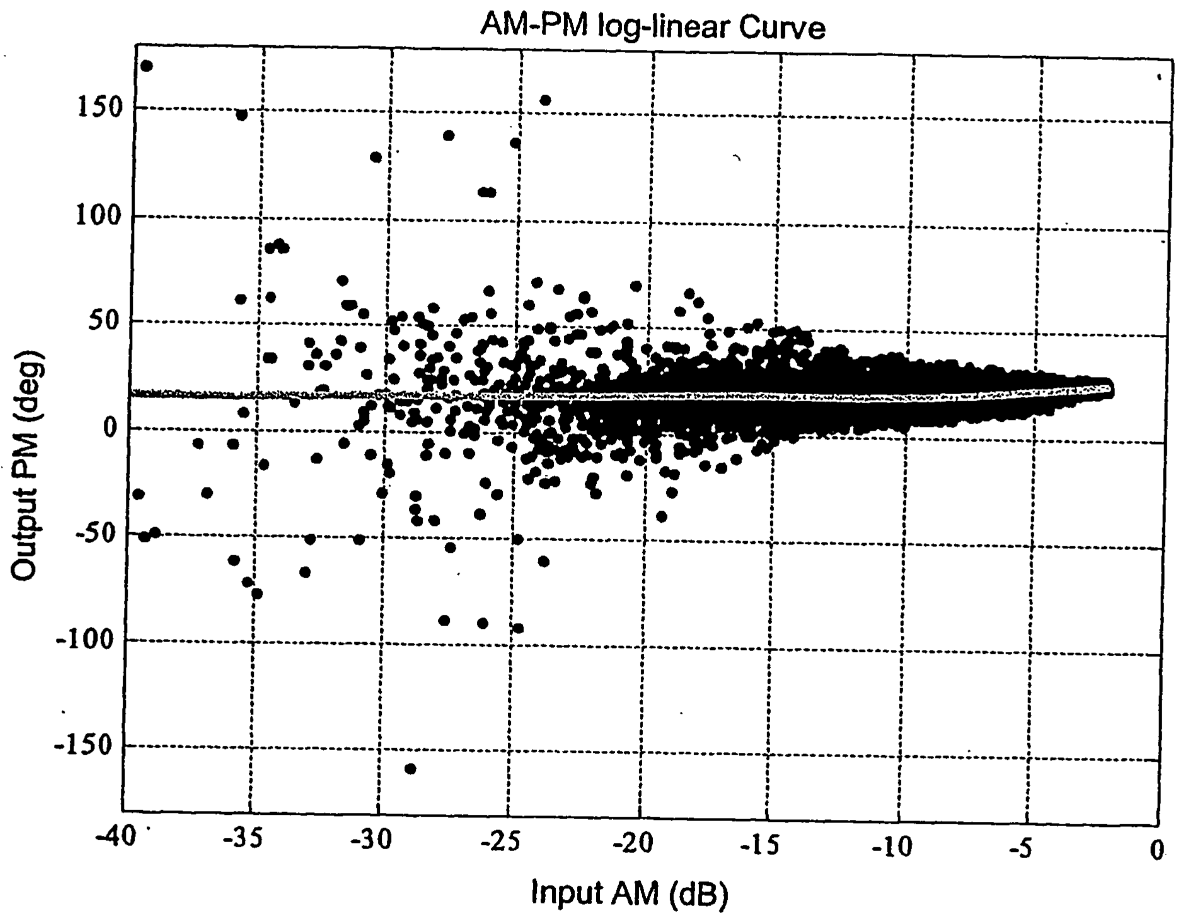

AM-PM log-linear Curve
150
100
50
0
-50
-100
-150
Output PM (deg)
-40
-35
-30
-25
-20
-15
-10
-5
0
Input AM (dB)

FIG. 12

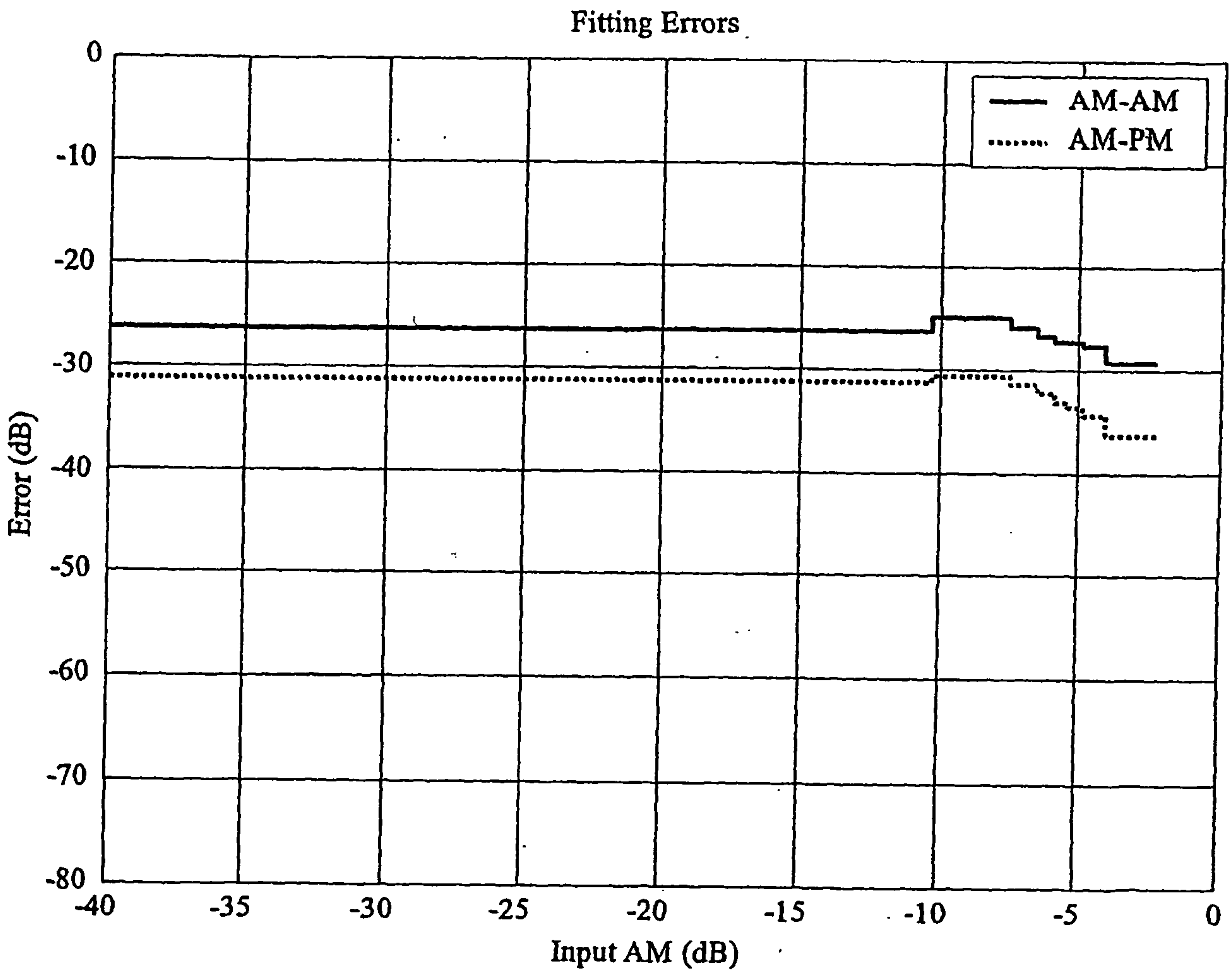

Fitting Errors
AM-AM
AM-PM
Error (dB)
0
-10
-20
-30
-40
-50
-60
-70
-80
-40
-35
-30
-25
-20
-15
-10
-5
0
Input AM (dB)

FIG. 13

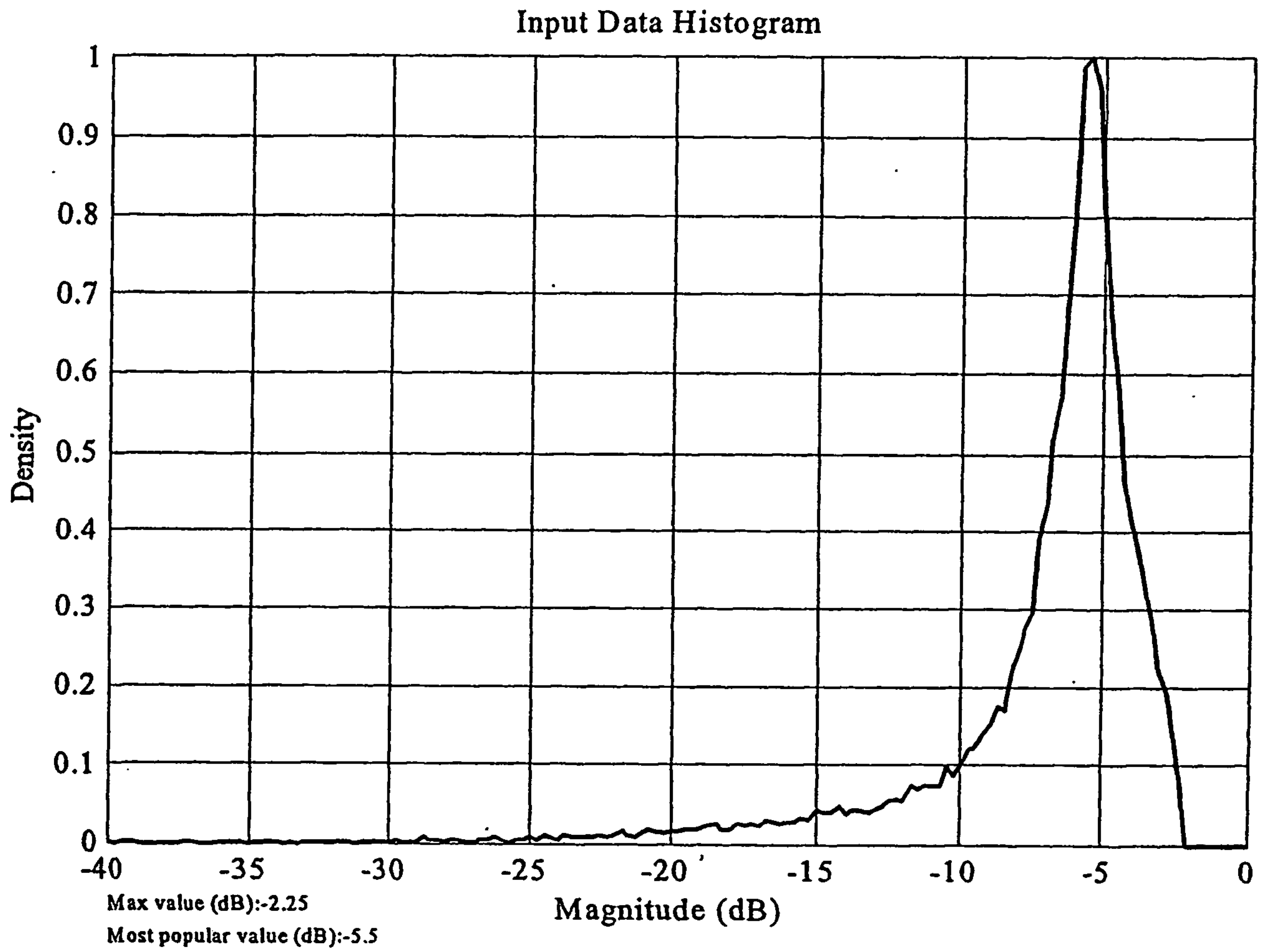

Input Data Histogram
Density
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-40
-35
-30
-25
-20
-15
-10
-5
0
Max value (dB):-2.25
Most popular value (dB):-5.5
Magnitude (dB)

FIG. 14

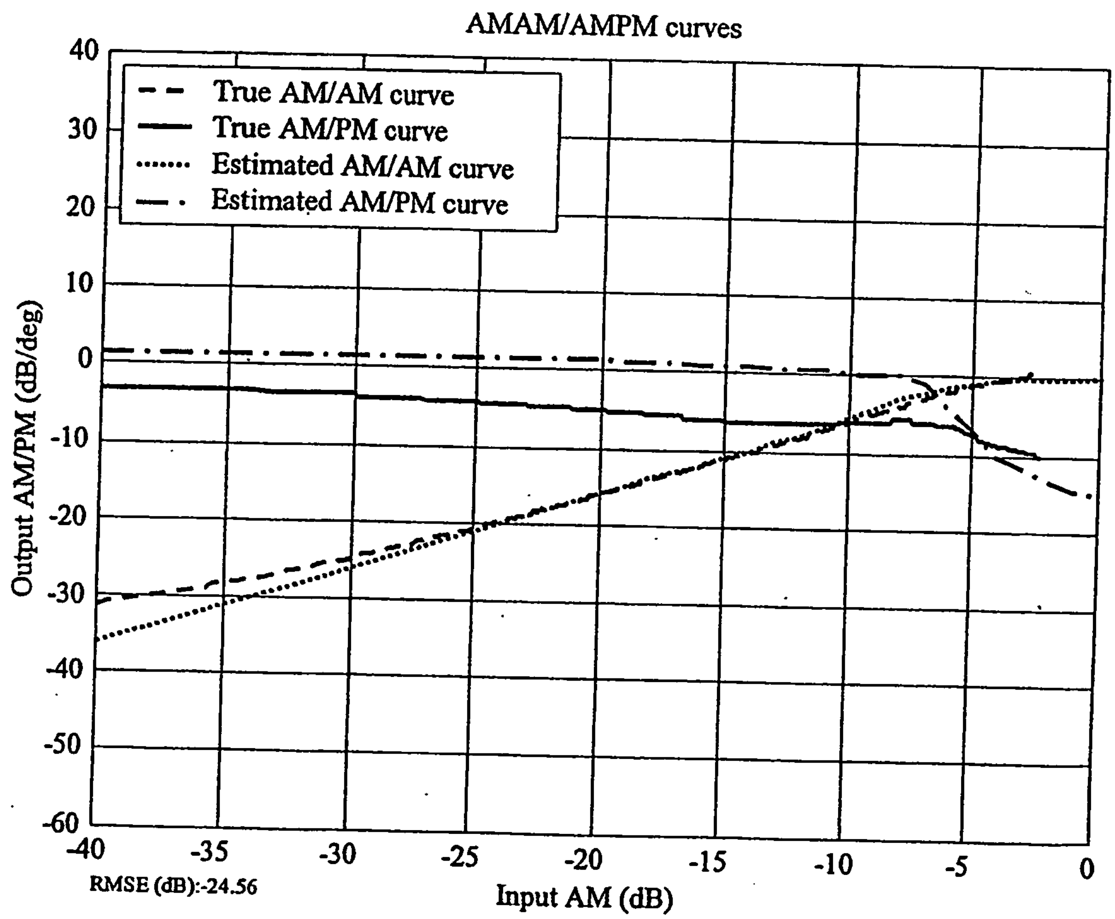

AMAM/AMPM curves
True AM/AM curve
True AM/PM curve
Estimated AM/AM curve
Estimated AM/PM curve
40
30
20
10
0
-10
-20
-30
-40
-50
-60
Output AM/PM (dB/deg)
-40
-35
-30
-25
-20
-15
-10
-5
0
RMSE (dB):-24.56
Input AM (dB)

FIG. 15

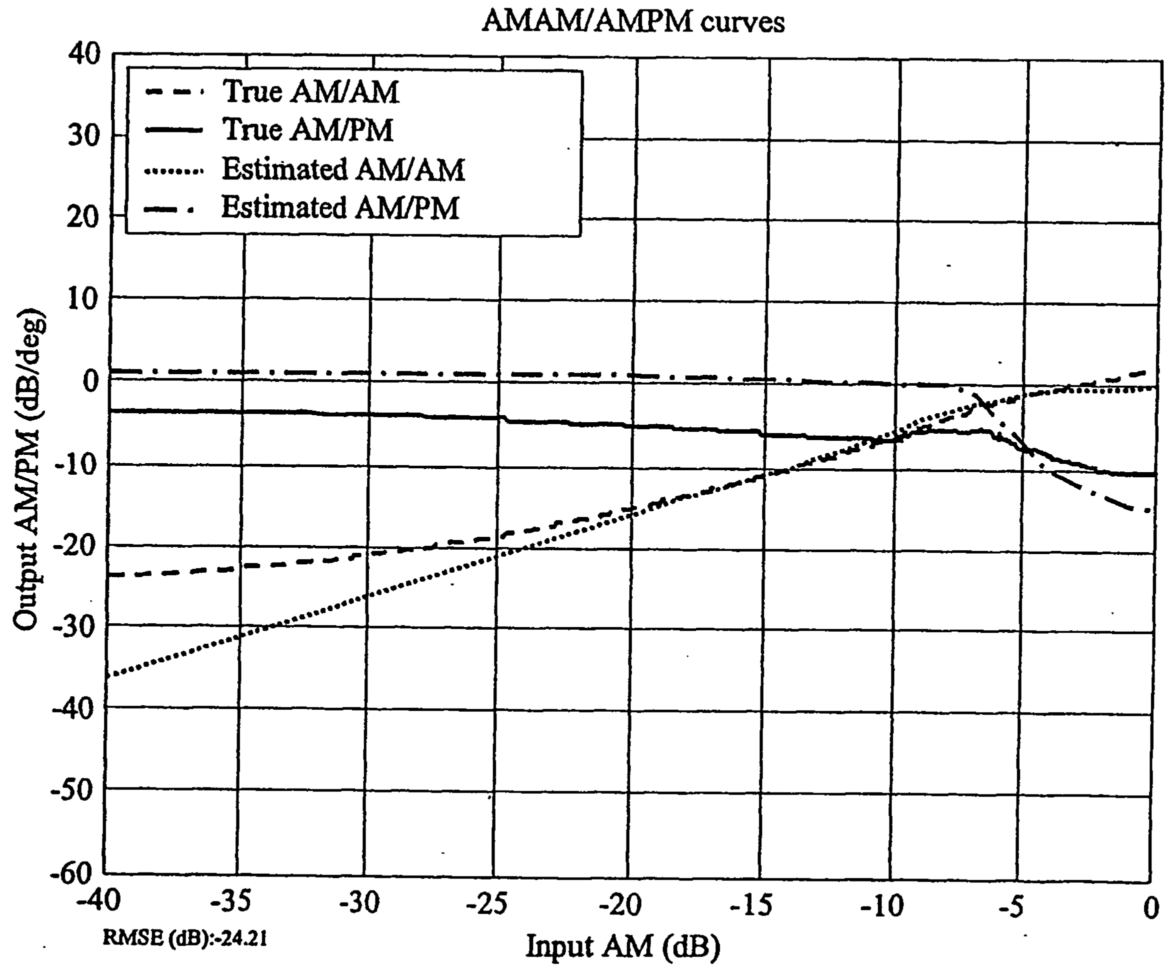

AMAM/AMPM curves
True AM/AM
True AM/PM
Estimated AM/AM
Estimated AM/PM
Output AM/PM (dB/deg)
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-40
-35
-30
-25
-20
-15
-10
-5
0
RMSE (dB):-24.21
Input AM (dB)

FIG. 16

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 03/17781

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H04B17/00 H04B7/185

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H04B H04L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, INSPEC, COMPENDEX

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	WO 00 79708 A (BETHSCHEIDER GERHARD ;SOC EUROP DES SATELLITES SA (LU); HARLES GUY) 28 December 2000 (2000-12-28) page 1, line 4 - line 6 page 1, line 33 -page 2, line 16; figure 1 page 5, line 21 -page 6, line 8 page 6, line 30 -page 7, line 10 page 8, line 26 - line 28 --- -/--	1-3, 16-21, 34-36 4-15, 22-33

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
7 October 2003	15/10/2003

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Sieben, S

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
Y	WO 01 80471 A (DOR AVNER ;DSPC TECH LTD (IL); YELLIN DANIEL (IL); BARAK ILAN (IL)) 25 October 2001 (2001-10-25)	4-15, 22-33
A		1-3, 16-21, 34-36
	page 1, line 6 - line 21; figure 1 page 4, line 26 - line 30; figures 3A,3B claims 1,3,4; figure 4	
A	WOLCOTT T J ET AL: "UPLINK-NOISE LIMITED SATELLITE CHANNELS" PROCEEDINGS OF THE MILITARY COMMUNICATIONS CONFERENCE (MILCOM). SAN DIEGO, NOV. 6 - 8, 1995, NEW YORK, IEEE, US, vol. 1, 6 November 1995 (1995-11-06), pages 717-721, XP000580915 ISBN: 0-7803-2490-0 page 717, left-hand column, last paragraph -right-hand column, paragraph 1 page 718, right-hand column, paragraph 4 - paragraph 5	1-36

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/US 03/17781

Patent document cited in search report		Publication date	Patent family member(s)			Publication date
WO 0079708	A	28-12-2000	WO	0079708	A1	28-12-2000
			AU	763129	B2	17-07-2003
			AU	4613699	A	09-01-2001
			BR	9917381	A	26-03-2002
			CA	2375846	A1	28-12-2000
			EP	1186126	A1	13-03-2002
			JP	2003502935	T	21-01-2003
			US	2002094015	A1	18-07-2002
WO 0180471	A	25-10-2001	AU	5062701	A	30-10-2001
			WO	0180471	A2	25-10-2001